“An assessment of carbon leakage in the light of the COP-15 pledges.”

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Overview

- Modelling methodology and calibration of a WIOD-GEM model
- COP-15 pledges
- Outlook for energy intensive industries
- Simulation results on carbon leakage

WIOD-GEM model

- The analysis was carried out using a computable general equilibrium model specifically constructed for the WIOD project and calibrated to the WIOD data.
- The WIOD-GEM model provides quantitative projections of the EU and the global economy for multiple sectors and endogenous trade as a result of sequentially dynamic general equilibria
- WIOD 2007 world input output tables serve as base year for calibration
- The simulated scenarios focus on competitiveness and economic activity by sector and by country in the context of GHG emission reduction actions
- The simulation period goes until 2050 in 5-years time steps

Regional and Sectorial coverage of the model

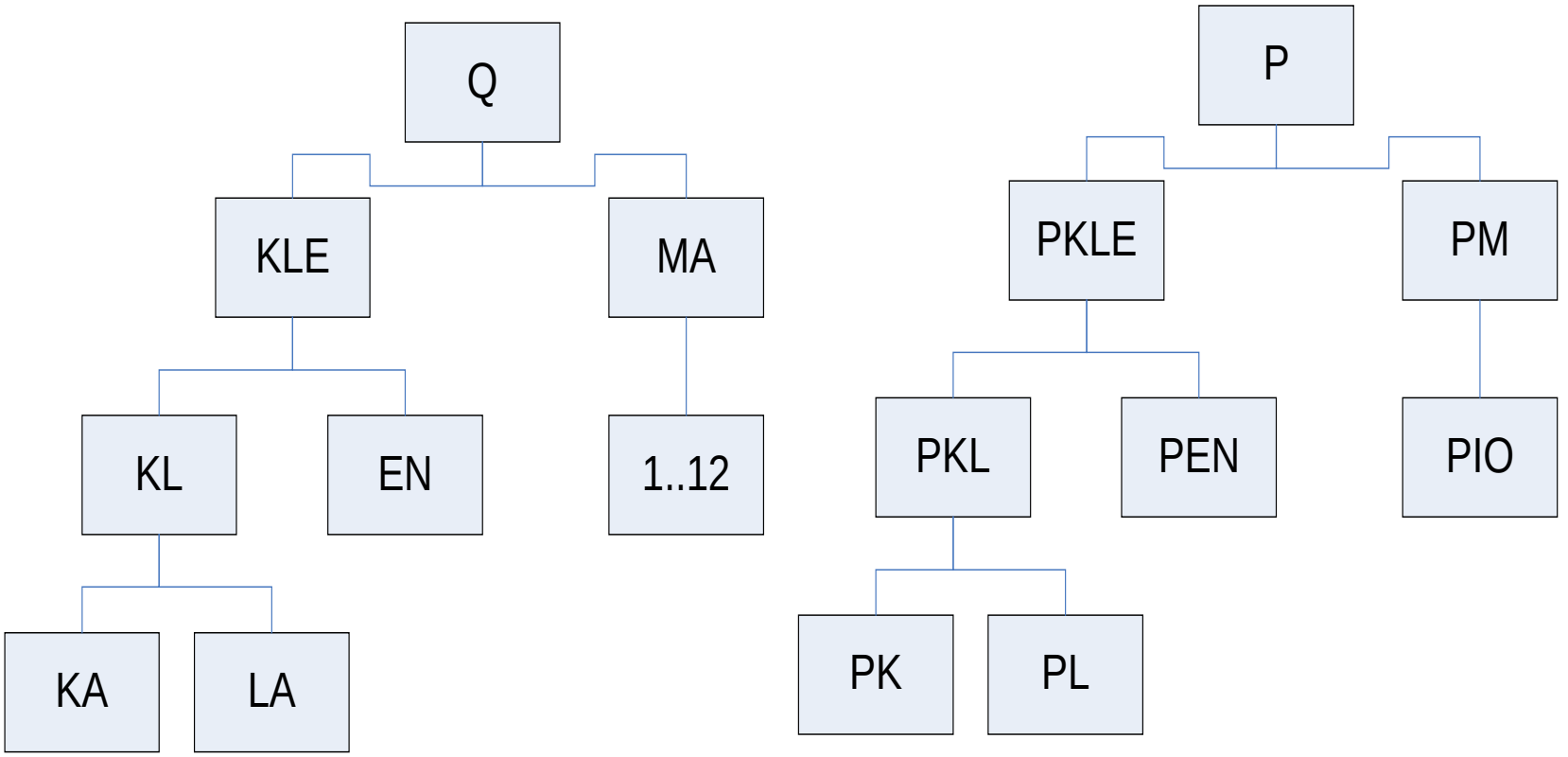
No	Activities		No	Acronym	Country
01	Agriculture		01	EU27	European Union
02	Mining		02	AUS	Australia
03	Energy		03	BRA	Brazil
04	Metals		04	NAM	USA and Canada
05	Chemical		05	JAK	Japan and Korea
06	Non metallic minerals		06	CHN	China
07	Paper products		07	IND	India
08	Consumer goods		08	ASI	Indonesia and Taiwan
09	Equipment Goods		09	RUS	Russia
10	Construction		10	ROW	Rest of the world
11	Market Services				
12	Non Market Services				
13	Transport				

Behaviour of producers

- A single representative producer operates by sector producing a homogeneous product which is differentiated from products of other sectors and countries
- Derived demand for production factors (KLEM) is endogenous resulting from cost minimization under constant economies of scale and perfect market competition
- The production technology is assumed to be CES (constant elasticity of substitution) with a nested structure

$$Q = \overline{Q} \cdot \left[\Theta_{KLE} \cdot \left(\frac{KLE}{\overline{KLE}} \right)^{\rho} + \Theta_{MA} \cdot \left(\frac{MA}{\overline{MA}} \right)^{\rho} \right]^{\frac{1}{\rho}}$$

CES nesting scheme



Behaviour of households

- A representative household is assumed to maximise utility under a budget constraint which derives from disposable income and a given savings rate
- Demand for goods and services derive from a single level CES budgeting

$$U = \sum_{i=1}^{n=13} \left(th_i \cdot \left(\frac{CV_i}{\overline{CV_i}} \right)^{ss} \right)^{\frac{1}{ss}} \qquad max_{CV}\ \mathrm{U(CV)}\ ,\ s.t.\ \mathrm{M} = YDISP$$

Investment by sector

- Investment by sector is based on the accelerator model (AM) and the *q* factor of Tobin (1969)
- Producers by sector determine investment by sector depending on the effective rate of return of sectoral capital relative to unit cost of building capital, the anticipation of future sector development (stgr) and the rate of replacement of existing capital stock

$$INVV = m \cdot K \cdot \left[\frac{P_k}{PINV \cdot (r + d)} \cdot (1 + stgr) - (1 - d)\right]$$

Capital accumulation

- The stock of capital by sector at a given period of time is fixed depending on previous period stock, capital replacement and new investment
- Producers use capital stock and determine factor mix according to a putty-putty assumption
- Building of investment by product of origin is determined through an investment matrix with exogenous technical coefficients

Primary factor markets

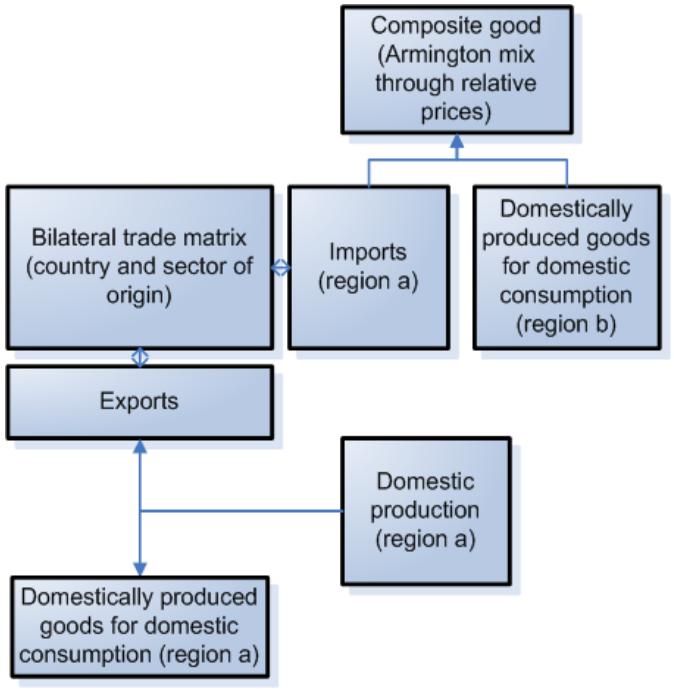
- Supply of capital financing depends on total savings, whereas demand for capital depends on investment. Capital is assumed mobile within a region; hence a regional rate of return of capital is derived from balancing supply and demand for capital at a regional level
- Labour supply is exogenous and is projected according to the "Ageing population report 2012" by DG ECFIN for the EU and the ILO projections for the non EU countries. Labour demand is derived from producer behaviour. Assuming perfect labour mobility only within a region, a region-wide wage rate is determined from equilibrium between labour supply and demand assuming no unemployment.

$$KS \geq KD \quad \perp \quad PK$$

$$LS \geq LD \quad \perp \quad P\,L$$

Trade

- The demand of products by consumers, by producers (for intermediate consumption and investment) and by the public sector (exogenous) form total domestic demand
- Total demand by product is met by domestically produced goods and imported goods which form a composite good following the Armington hypothesis
- Under a perfect competition hypothesis all demanders are price takers and prices do not differentiate between the domestic and the exporting markets
- Demanders are assumed minimising costs to determine the mix between imports and purchases from the domestic market



Emissions

- The WIOD database identifies two energy sectors namely: i) Coke, Refined Petroleum and Nuclear Fuel and ii) Electricity, Gas and Water Supply.
- Splitting the energy sectors to their components has not attempted. We should use information regarding prices and the energy balances of each country/region.
- To simulate emission reduction possibilities we use marginal abatement cost curves by sector for CO2 energy related emissions and for non-energy related GHG emissions. The CO2 energy related MACCs are derived from the energy-specific PRIMES and POLES models whereas the non-energy related MACCs are estimated from EPA (2006) data.

Government

- The government behavior is assumed exogenous in the model.
- Government raises taxes and provides subsidies at given rates. Government's finance budget influence total savings and affects the capital market.
- Government's policy for income distribution (given rates are used for income tax and social benefits) influence disposable income of households
- Government's demand for goods and services is determined from exogenous public consumption and investment.

COP-15 pledges (as defined in Copenhagen)

	Countries	GHG mt		Target (2020) low pledge		Target (2020) high pledge	
		1990	2005	rel 1990	rel 2005	rel 1990	rel 2005
ANNEX I	Australia	416	525	13%	-10%	-11%	-29%
	Belarus	129	77	-5%	58%	-10%	50%
	Canada	592	731	-3%	-21%	-3%	-21%
	Croatia	31	30	6%	9%	6%	9%
	EU27	5573	5119	-20%	-14%	-30%	-24%
	Iceland	3	4	-15%	-22%	-15%	-22%
	Japan	1270	1358	-25%	-30%	-25%	-30%
	New Zealand	62	77	-10%	-28%	-20%	-36%
	Norway	50	54	-30%	-35%	-40%	-44%
	Russia	3319	2118	-20%	25%	-25%	18%
	Switzerland	53	54	-20%	-21%	-30%	-31%
	Ukraine	926	418	-20%	77%	-20%	77%
	USA	6084	7107	-3%	-17%	-3%	-17%
NON ANNEX I	Mexico		688		-16%		-16%
	South Korea		583		-4%		-4,0%
	Brazil*		989	-36% from BAU		-36% from BAU	
	China		6846	-40% in CO2/GDP on 2005		-40% in CO2/GDP on 2005	
	India		1788	-20% in C/GDP		-20% in C/GDP	
	Indonesia*		584	-26% from BAU		-41% from BAU	
	South Africa		445	-34% from BAU		-42% from BAU	
	Singapore		46	-16% from BAU		-16% from BAU	

GHG emission reduction in the scenario

- The low pledges were assumed to apply for regional GHG emission reduction targets for 2020. The intensity of emission reduction commitments is assumed to remain constant in the period 2020-2050 with the exception of the EU which continues the decrease of ETS allowances beyond 2020.
- In a decarbonisation scenario the EU reduces GHG emissions by 78% in 2050 compared to 2005 (see table below).

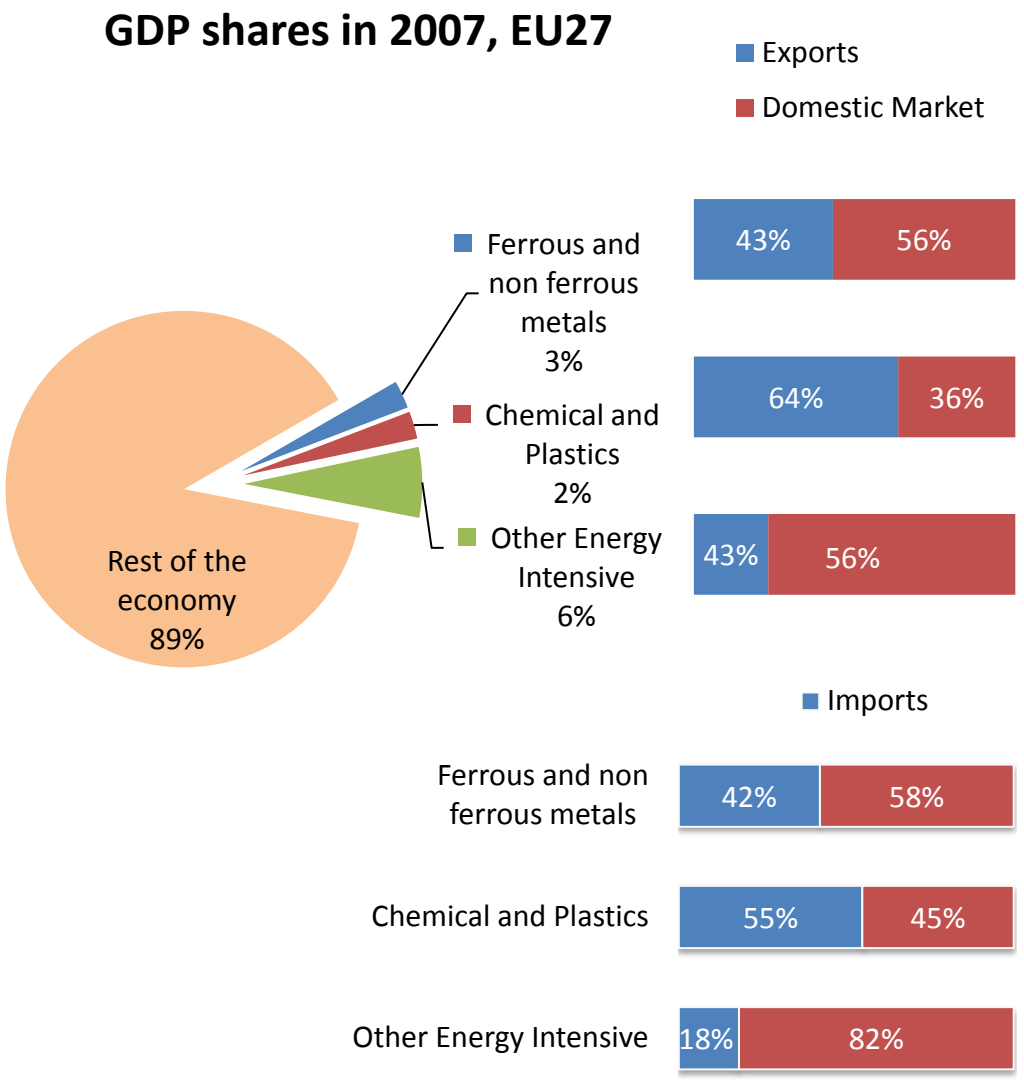
	2015	2020	2025	2030	2035	2040	2045	2050
EU27	-12%	-24%	-34%	-42%	-51%	-60%	-69%	-78%
North America	-12%	-17%						
Japan and Korea	-11%	-22%						
Australia	-5%	-10%						
Russian fed.	32%	25%						
Brazil	-	-						
China	-	-						
India	-	-						
Rest of Annex I	-	-						
RoW	-	-						

Energy Intensive Industries

- In the model energy intensive industries are classified in four sectors: metals, chemicals, non-metallic minerals and paper products. The energy intensive industries are strongly exposed to trade competition. The electricity and transport sectors are assumed to address the domestic markets.
- The EU performing emission reduction unilaterally implies that a carbon price applies on the EU economy. The prices of energy intensive industries tend to increase as carbon prices apply on intermediate inputs, directly and indirectly through electricity prices. Therefore, the EU position in global trade weakens and energy intensive products are increasingly produced in non EU countries.
- Consequently, part of the emission reduction in the EU is lost at a global scale as emissions in the non EU countries tend to increase. The loss is known as carbon leakage.

Share of energy intensive industries in EU27 GDP and foreign exposure

- Metals and chemicals are far more exposed to foreign competition than other energy intensive industries, as the latter primarily address domestic construction industry
- Higher prices of energy intensive materials due to carbon prices will affect trade position of the EU in the market for chemicals and metals, whereas the same price increases in other energy intensive products will mainly reduce domestic demand



Regional shares in Energy Intensive Production in 2007

	Australia	Brazil	China	India	Russia	Rest of the World	EU27	North America	Japan and Korea	Indonesia and Taiwan
Metals	1,7%	1,8%	19,8%	3,2%	2,6%	12,7%	26,3%	14,5%	15,5%	1,9%
Chemicals	0,7%	2,5%	18,8%	2,4%	1,2%	11,6%	27,1%	20,8%	12,2%	2,6%
Non metallic minerals	1,2%	1,7%	26,4%	3,1%	3,2%	13,1%	29,1%	12,3%	8,5%	1,4%
Paper products	1,4%	1,9%	12,3%	1,3%	1,4%	14,1%	31,3%	26,5%	8,3%	1,5%
Total production	1,2%	2,1%	18,6%	2,6%	1,9%	12,6%	27,7%	18,7%	12,4%	2,0%

- The main producers of energy intensive products are the EU, North America and China representing the 65% of world production.

Simulation Results of a EU alone decarbonisation scenario

- The carbon prices are derived using the model and depend on differentiated regional emission reduction targets
- The EU will require high carbon prices to perform decarbonisation, while the other regions need rather low and constant carbon prices to implement the pledges

Carbon prices in EURO'2007/tCO_2								
	2015	2020	2025	2030	2035	2040	2045	2050
Australia	9	18	18	18	18	18	18	18
EU27	9,5	19	27	32	37	43	151	284
North America	6	12	12	12	12	12	12	12
Japan and Korea	7	15	15	15	15	15	15	15

Macroeconomic impacts for EU27 from unilateral climate action

- The carbon prices imply higher domestic prices in all sectors which primarily imply lower domestic demand, compared to baseline
- Lower domestic demand implies lower demand for labour, thus lower wage rates which further drive contraction of private consumption, with negative effects on welfare
- In addition, the EU competitiveness is undermined implying lower exports
- Lower imports are due to lower domestic demand
- Investment is slightly higher than in baseline, as fossil fuel imports are substituted by goods and services implementing low carbon technologies and energy efficiency and so domestic production of equipment goods tend to increase relative to baseline

in % changes from baseline	2020	2030	2040	2050
Gross Domestic Product	-0,10	-0,19	-0,30	-2,11
Investment	0,00	0,01	0,02	0,10
Private Consumption	-0,18	-0,33	-0,52	-3,50
Exports	-0,11	-0,23	-0,41	-3,00
Imports	-0,18	-0,35	-0,53	-3,26

GDP Impacts on non EU countries

- The impacts on the non EU regions are small and are mostly due to lower demand by the EU
- Regions that increase production to substitute for the more expensive EU products may see GDP gains relative to baseline
- Fossil fuel exporters, as for example Russia, see negative impacts on GDP due to lower fossil fuel exports

% change of GDP from baseline	2050
North America	-0,02
Japan and Korea	-0,02
Australia	0,03
China	0,03
India	0,02
Brazil	0,13
Russia	-0,49
Indonesia and Taiwan	0,12
Rest of the World	0,07

Production by sector in the EU alone scenario

- The non EU regions bear little effects which are mainly due to lower demand by the EU for imports
- In energy intensive industries production in non EU regions increases, relative to baseline, while EU production strongly decreases

	EU27	North America	Japan and Korea	Australia	China	India	Brazil	Russia	Indonesia and Taiwan	Rest of the World
Agriculture	-0,46	-0,40	-0,18	-0,33	-0,01	-0,03	-0,54	-0,66	-0,19	-0,32
Mining	-4,08	0,15	-0,43	-0,03	0,27	0,12	0,05	-3,27	0,25	-0,07
Energy	-11,48	0,64	0,12	0,19	0,39	0,35	1,05	0,99	1,48	1,58
Metals	-5,86	0,94	0,81	1,21	0,23	0,34	1,45	1,63	1,56	0,86
Chemical	-11,48	1,31	-0,19	2,16	0,80	0,78	1,81	2,95	2,15	2,76
Non metallic minerals	-7,98	0,84	0,50	0,62	0,23	0,64	1,32	0,58	0,88	1,65
Paper products	-4,49	0,42	0,04	0,50	0,18	0,41	0,98	1,13	0,63	0,99
Consumer goods	-0,90	-0,22	-0,20	-0,34	-0,15	-0,06	-0,19	-0,61	-0,41	-0,39
Equipment Goods	-1,19	0,09	-0,16	0,02	-0,07	0,05	0,23	-0,07	-0,24	-0,06
Construction	-0,52	0,00	0,00	0,00	-0,04	0,01	0,01	-0,05	0,02	0,00
Market Services	-1,20	-0,17	-0,11	-0,13	-0,27	-0,14	-0,08	-0,76	-0,10	-0,31
Non Market Services	-1,26	-0,04	-0,04	-0,02	0,04	0,04	0,07	-0,26	0,17	0,03
Transport	-10,31	0,54	0,83	1,08	0,83	0,18	0,69	3,45	0,99	1,71

Changes in regional shares of energy intensive production

- The EU market shares decrease
- The highest increase is found for China

Differences of shares from baseline in 2050	Australia	Brazil	China	India	Russia	Rest of the World	EU27	North America	Japan and Korea	Indonesia and Taiwan
Metals	0,01%	0,01%	0,18%	0,04%	0,01%	0,06%	-0,37%	0,03%	0,03%	0,02%
Chemical	0,00%	0,01%	0,50%	0,04%	0,01%	0,12%	-0,76%	0,05%	-0,01%	0,03%
Non metallic minerals	0,00%	0,00%	0,21%	0,06%	0,00%	0,07%	-0,36%	0,01%	0,00%	0,00%
Paper products	0,00%	0,01%	0,24%	0,03%	0,01%	0,10%	-0,45%	0,05%	0,00%	0,01%

Carbon Leakage

- Carbon leakage is defined as the increase in CO_2 emissions outside EU divided by the reduction in the emissions of EU
- We calculate the carbon leakage for cumulative CO_2 emissions over 2015 -2020 for the COP15 pledges period and over 2025-2050 for the period when EU acts alone
- We find that in the COP-15 implementation phase the carbon leakage is 0.3% and for the 2025-2050 period it is 3.41%.

Sensitivity analysis for carbon Leakage

- The results depend on the assumed Armington elasticities
- A sensitivity analysis for various Armington elasticities was carried out
- We find that the carbon leakage in the period 2025-205 varies from 1.32% to 10.84% with varying Armington elasticities

Armington elasticities		Carbon Leakage (2015-2020)	Carbon Leakage (2025-2050)
Domestic versus Imported	**Imports from different regional origins**		
2	**4**	0.1%	1.32%
4 (default)	**8 (default)**	0.3%	3.41%
8	**16**	0.8%	7.33%
12	**24**	1.35%	10.84%

Conclusions

- The WIOD database has been used to calibrate a multi country multi regional CGE model to year 2007
- The model was used to estimate carbon leakage resulting from implementation of the COP-15 pledges in 2020 and from a unilateral EU emission reduction action in the period 2025 to 2050.
- The carbon leakage for the period 2015-2020 is estimated to be in the range of 0.1% to 1.35% depending on the values of Armington elasticities. In the period when the EU acts alone the carbon leakage ranges from 1.32% to 10.84%.
- Significant impacts on the EU economy are found with the EU increasingly losing market share in the global markets for energy intensive products